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For the past few years, the Space and Naval Warfare Systems Command (SPAWAR) has been developing a Naval Architecture Database (NAD) designed to integrate the Navy's C4ISR operational, systems, and technical architectures in order to support users represented by the program managers, systems engineers, and their equivalents at other CINCs/Services/Agencies. Several systems related applications, models, and tools use this architectural information to support C4ISR decision making. Each of these applications addresses a different and specialized aspect of the systems engineering process. Addressed from an architectural level, it appears that most if not all of these applications may be supported by the same set of C4ISR systems related data. Process and business efficiencies can be realized if a centralized information repository is populated in order to distribute accurate and timely information to support all systems engineering applications. Metadata and production datafills could and should be shared. Once the central repository is established, various different systems applications may be added to a modular structure, easing change management. A fully populated central architecture repository could also be used to provide decision support systems with the capability to query across systems application boundaries to provide management with forecasting, trend analysis, and knowledge-based capabilities combining topics such as fleet deployment, systems capabilities, budget modeling, and systems architecture. This paper describes the C4ISR systems engineering requirements that we have gathered and the methodologies that we have applied in building a central architecture repository to provide C4ISR systems interoperability information. We will describe several initiatives within the Command which require an integrated enterprise solution which we will describe in the paper. As our project is not completed, the paper also includes not only expected benefits, but also issues that need to be resolved before a production systems interoperability repository is fully functioning.

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A CENTRAL ARCHITECTURE REPOSITORY FOR C4ISR SYSTEMS INTEROPERABILITY

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ABSTRACT

For the past few years, the Space and Naval Warfare Systems Command (SPAWAR) has been developing a Naval Architecture Database (NAD) designed to integrate the Navy's C4ISR operational, systems, and technical architectures in order to support users represented by the program managers, systems engineers, and their equivalents at other CINCs/Services/Agencies. Several systems related applications, models, and tools use this architectural information to support C4ISR decision making. Each of these applications addresses a different and specialized aspect of the systems engineering process. Addressed from an architectural level, it appears that most if not all of these applications may be supported by the same set of C4ISR systems related data. Process and business efficiencies can be realized if a centralized information repository is populated in order to distribute accurate and timely information to support all systems engineering applications. Metadata and production datafills could and should be shared. Once the central repository is established, various different systems applications may be added to a modular structure, easing change management. A fully populated central architecture repository could also be used to provide decision support systems with the capability to query across systems application boundaries to provide management with forecasting, trend analysis, and knowledge-based capabilities combining topics such as fleet deployment, systems capabilities, budget modeling, and systems architecture. This paper describes the C4ISR systems engineering requirements that we have gathered and the methodologies that we have applied in building a central architecture repository to provide C4ISR systems interoperability information. We will describe several initiatives within the Command which require an integrated enterprise solution which we will describe in the paper. As our project is not completed, the paper also includes not only expected benefits, but also issues that need to be resolved before a production systems interoperability repository is fully functioning.

BACKGROUND/INTRODUCTION

The Office of the Chief Engineer at the Space and Naval Warfare Systems Command (SPAWAR-05) provides unifying management and technical direction for the development, delivery and support of Naval C4ISR systems. In order to streamline the Information Technology acquisition process of the command, an information infrastructure must be matured to meet the demand of an 18-month procurement cycle critical to remaining inside the commercial technology cycle. C4ISR acquisitions must start with an architectural view of the current and projected systems implementations to determine where and how a new acquisition will fit into the existing infrastructure. Figure 1 of the organizational structure of SPAWARSYSCOM illustrates the span of responsibility and consequently, requirements necessary to support an interoperable C4ISR solution, making portions of the organization responsible for the system from cradle to grave.

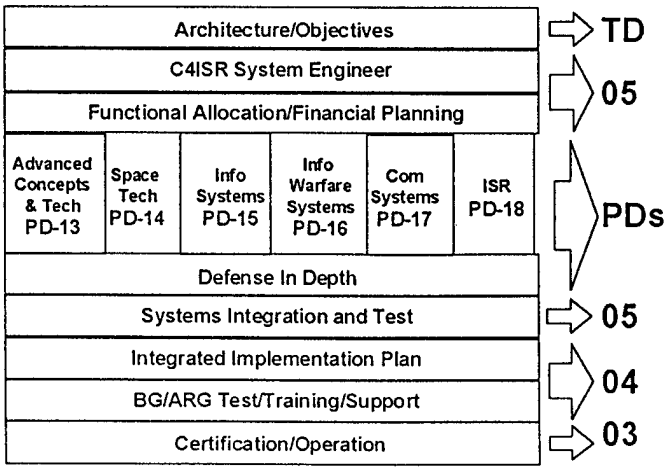

Figure 1: SPAWAR organization [1]

REQUIREMENTS

Architecture is defined in the C4ISR Architecture Framework 2.0 [2] as the structure of components, their relationships, and the principles and guidelines governing their design and evolution over time.

Interoperability, as applied to the C4ISR systems engineering, is defined as "the ability of systems, units, or forces to provide services to or accept services from other systems, units, or forces and to use the services so exchanged to operate effectively together. The conditions achieved among communications-electronics systems or items of communications-electronics equipment when information or services can be exchanged directly and satisfactorily between them and/or their users." [3]

In C4ISR systems acquisition, several areas require authoritative, centralized data:

1. Interoperability Analysis
2. Budget Modeling
3. Systems Capabilities mapping and analysis
4. C4ISR Architecture drawings (Ring Charts)
5. Configuration management tracking
6. Logistics support information
7. C4ISR Measures of Effectiveness and Performance to support Test and Evaluation
8. Critical system attributes to feed M&S
9. Tactical tasks performed by C4ISR systems
10. Systems performance data

Given the above business requirements to field interoperable systems, we have taken an innovative approach in extracting, transforming, and loading critical information into a central repository which allows command-wide synchronization for the current and planned state of the naval C4ISR. This integrated information warehouse and repository will allow a global view of C4ISR and allow managers to make informed decisions with the depth and breadth necessary to maximize the use of critically short funding in the Department of Navy today.

THE METHODOLOGY/ARCHITECTURE

This project has delineated critical areas in the C4ISR acquisition infrastructure that require centralized, normalized, and integrated information to insure that our acquisitions truly follow the SPAWAR mission to "deliver supportable, affordable, integrated, and interoperable world class information solutions."

SYSTEMS ARCHITECTURE

In order to field an interoperable system, a documented C4ISR current architecture must exist to understand a system's inter-relationships with other systems. Additionally, a target architecture must be developed to support the Operational Architecture of the future. A Naval Architecture Database[4], developed at SPAWAR 051, containing all the Naval C4ISR Systems, Operational, and Technical Architecture views will support C4ISR architecture analysis, both As-Is and Target architectures with fully attributed Information Exchange Requirements tied to tactical tasks and the available standards used to manipulate and transmit the information.

The Joint C4ISR Architecture/Planning and Analysis System (JCAPS) is a suite of tools. This toolbox allows the user to access existing and future C4ISR architectures and visualize them in the Framework 2.0 format as directed by OSD. These architectures will be used to support C4ISR Master Plans required in the DoD 5000.2 process. These operational, system, and technical views of the architecture will allow the user to manipulate the architecture and understand the ripple effects of proposed or actual changes to the infrastructure. The Core Architecture Data Model 2.0 [5] has been mapped to the Naval Architecture Data Model 2.1 [4] with 98% congruence. This compatibility will allow users of the NAD to exchange architecture data with other CINCs/Services/Agencies.

SYSTEMS ENGINEERING

In order to design a system to inter-operate with several legacy systems, a detailed understanding of the installed systems must exist. Representations of this complex infrastructure must be simple enough for human understanding of the first and second order effects of a decision made within the systems engineering process. The use of C4ISR As-Is Architecture drawings called "Ring Charts" are used to visualize the relationships between systems drilling through a hierarchy starting at the battle group level down to a particular component of a platform. As these drawings are developed, COTS drawing packages will generate the data behind these drawings to establish the relationships, links, and attributes associated with those systems. The example shown in Figure 2 is representative of a system-level Ring Chart for an aircraft carrier.

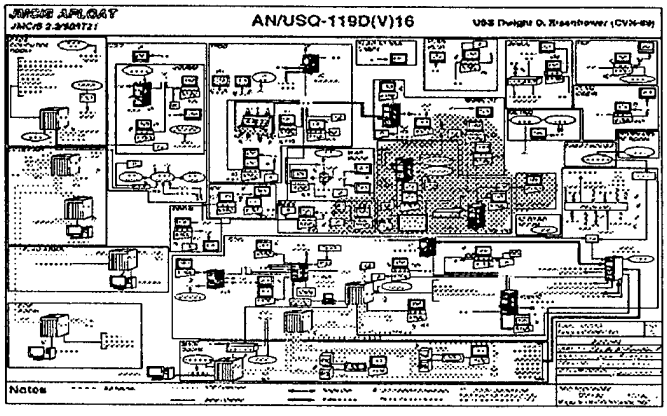

Figure 2: C4ISR Ring Chart

YEAR 2000 COMPLIANCE (Y2K)

All current and projected systems must be Y2K compliant. In order to facilitate compliance, systems must be tracked from a centralized location and an up-to-date status of the testing stored. Additionally, Memorandums of Agreement (MOA) are generated between program offices to insure that an agreed interface protocol exists to insure that Y2K interfaces are compliant. Integration of the Navy-wide Y2K compliance database with the C4ISR architecture is critical in understanding the Navy infrastructure vulnerabilities. The ability to trace Y2K compliance throughout C4ISR architecture should be built-in as systems are being added to the Naval Architecture Database.

VISION DOCUMENTS

There are several visions and proposed architectures that need to be mapped against the current C4ISR architecture in order to develop well planned migration plans.

- Information Technology for the 21st Century
- Joint Vision 2010
- Copernicus Forward
- Navy Virtual Internet
- Integrated Information Base Architecture

In order to be truly interoperable with the tactical environment, we need to insure that the infrastructure that is established in the non-tactical environment will be interoperable with the operational environment. For instance, the naming convention (noun name, hull number or some defined combination) for fleet units needs to be consistent across all systems.

SYSTEMS MANAGEMENT INTEGRATED DATA BASE (SMIDB)

For the installation of systems to support the Navy Virtual Internet (NVI), a proposed architecture, and Information Technology for the 21st Century (IT21),

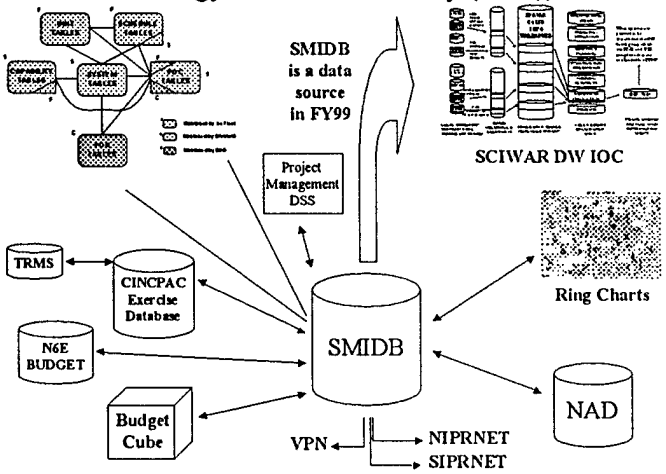

Figure 3: SMIDB integration to information warehouse

a technology insertion program must tie directly to fleet capabilities, mission requirements, the UJTLs, and battle groups entities.

A management tool allowing a user to visualize the interaction among schedule, money, platforms, systems, organizations, and capabilities is critical to the planning process. In order to fully integrate these information sources, data extraction, transformation, and loading from several legacy systems must occur in order to populate the database. Migration to a centralized repository as shown in Figure 3 is critical to making the system a viable, long-term decision support.

INTEROPERABILITY EVALUATION

The Level of Information Systems Interoperability (LISI), sponsored by OSD/ASD(C3I) and developed by Mitre, is a tool that allows the user to quantify a level of interoperability for a system across procedures, applications, infrastructure, and data domains. A measure of interoperability across all systems is required to understand where capability holes exist in the procedures, applications, infrastructure, and data to support an interoperable environment. SPAWAR is currently evaluating the technical reference model of LISI against several operational C4ISR systems. A representation of the current levels of interoperability is shown in Figure 4. This system is planned to be part of the SPAWAR acquisition tool kit that is fed with data from the NAD. Results of the evaluation will also be archived in the NAD throughout the system lifecycle.

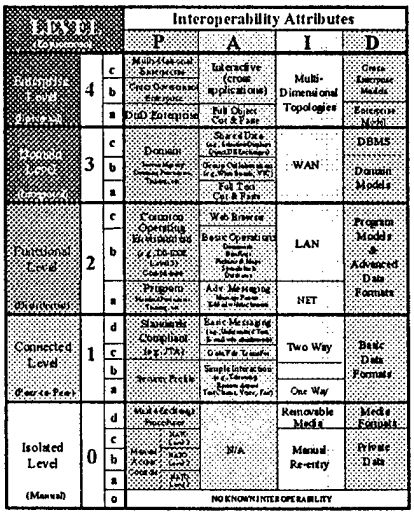

Figure 4: LISI C4ISR Assessment model [6]

MODELING AND SIMULATION SUPPORT

The Joint Maritime Systems Analysis Center (JMSAC) at SPAWAR PD13 and the Joint Chiefs of Staff (JCS) NetWars initiative are attempts to evaluate the performance of a C4ISR infrastructure for a specific mission and

phase of war. The capability to identify infrastructure shortfalls in the architecture of a particular battle group before a mission is critical to mission planning accuracy. Reuse of actual, measured data from exercises around the world help model the anticipated message traffic associated with a particular mission. This planning can identify bottlenecks in the C4ISR infrastructure and provide insight into the appropriate technical or operational work required to repair the anticipated problems prior to experiencing them in the operational environment. JMSAC is a COTS based tool that provides simple and quick evaluation of existing and to-be C4ISR architectures.

BUDGET MODELING

To ensure that the budget provided by CNO N6E at the Program Element (PE) level feed the Work Breakdown Structure (WBS) at SPAWAR, we must trace the money from the Congressional Budget to actual expenditure of assets. Funds must be tied to capabilities by battle group. Web-based integration of the Data CUBE database with the NAD and SMIDB will feature smart allocation of resources to meet current tactical task requirements, and further ties budget to existing infrastructure. It is desirable that a Baseline Assessment Memorandum (BAM) can be performed on these integrated databases where optimal slice and dice of financial resources may be proposed.

FLEET EXERCISE

As-Is C4ISR architecture performance data will be captured on operational systems through the Joint Network Management System and be used to validate the existing database content design assumptions, as well as feed scenario based modeling and simulation.

TYING IT ALL TOGETHER

The automation of Information Systems management and sharing of packaged application data has brought substantial and rewarding efficiencies to commercial business. These rewards are realized when more timely, accurate and comprehensive decisions are possible. Without a centralized, normalized, and distributed information architecture, critical decisions cannot be made on all the associated facts. In order to facilitate a common information base for the command acquisition infrastructure, we have developed a high-level information architecture to tie those disparate data sources together. Data warehousing and virtual data base technologies combined with web distribution allow smart push and pull of the appropriate information to the user. While we will be gathering all the critical data elements into the data warehouse repository (Figure 5) with a single metadata management area, we will be able to deliver appropriately sized and subject specific aggregations of authoritative data to information customers to support the various business requirements (Figure 6) throughout the Command. The final SPAWAR C4ISR Information Warehouse and Repository (SCIWAR) Operating Capability architecture is shown in Figure 7.

BENEFITS

Each application runs on a data mart produced by the data warehouse will have the latest aggregation of information to support their business process, to include

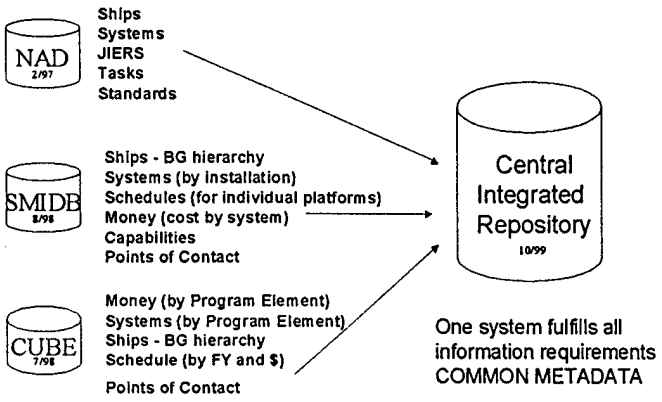

Figure 5: Migration of information into a repository

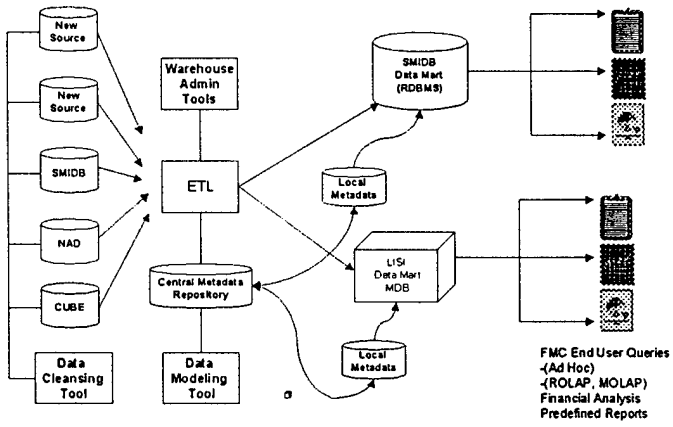

Figure 6: True ETL using Data Warehouse technology

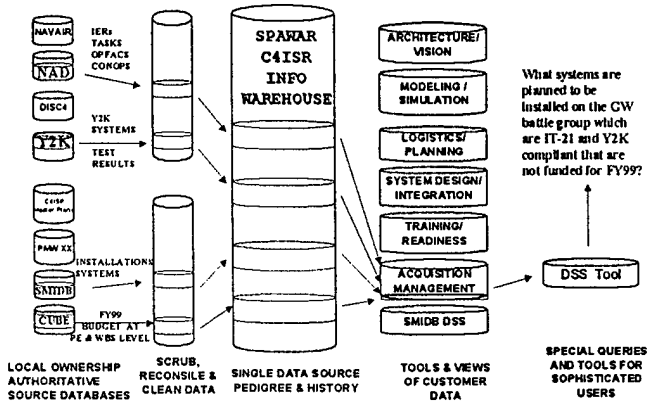

Figure 7: Initial Operating Capability Architecture

the historical data which allows the added feature of trend and time variance analysis. The open system architecture facilitated by standardized information syntax, semantics, and web-based distribution technologies is a large benefit facilitating more interoperable, Command wide tool sets. The fact that new detailed analysis can occur with centralized information will provide results with more breadth and depth allowing more discrete analytical capability. The addition of knowledge base and data mining technologies will allow new trends and capabilities to be discovered while also adding cognitive reasoning capability against an authoritative source of information for the command. Once the data warehouse infrastructure is fully architected and established, new data sources and marts can be rapidly inserted into the architecture allowing quick response and access to critical information. Additionally, rapid versioning of the data marts keeps the business applications current to meet the changing business requirements.

ISSUES

Several implementation and supportability issues exist in our project. The technical feasibility is being verified as we are bringing disparate data together. This will be demonstrated by a Proof of Concept near the end of this calendar year. Information security is a high priority. An aggregation of unclassified data can result in a query which becomes classified. Multi-level security and row level data access may be required to truly automate the integrated data environment use and information distribution. It is critical that data ownership be specifically established so that timely and valid system engineering data are available to represent diversified, yet integrated aspects of C4ISR systems. At the same time, continued management support and user involvement are required before a Naval Central Architecture Repository for C4ISR Systems Interoperability can become a production reality.

CONCLUSION

A central information repository is required to achieve true interoperability into the C4ISR architecture.

The current state of technology is available to facilitate automated extraction, transformation, and loading of information and delivering authoritative, aggregations of data to a specific user. Certainly, data warehouse technology is one of the major technical solutions to centrally managing the Command's metadata requirements and increasing the interoperability of information itself across the command.

ACKNOWLEDGEMENTS

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ACRONYMS

ASD(C3I)	Assistant Secretary of Defense, C3I
BAM	Baseline Assessment Memorandum
CINC	Commander-In-Chief
CINCPCTFLT	Commander-In-Chief of the Pacific Fleet
C3I	Command, Control, Communications, Intelligence
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
CNO	Chief of Naval Operations
COTS	Commercial Off The Shelf
DSS	Decision Support System
DW	Data Warehouse
ETL	Extract, Transform, Load
JCAPS	Joint C4ISR Analysis & Planning System
JMSAC	Joint Maritime Systems Analysis Center
LISI	Levels of Information Systems Interoperability
M&S	Modeling and Simulation
MOA	Memorandum of Agreement
NAD	Naval Architecture Database
OSD	Office of the Secretary of Defense
PD	Program Director
SMIDB	System Management Integrated Data Base
TRM	Technical Reference Model
UJTL	Universal Joint Task List

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